ESP-CARRIERS-SOO-001

455 / EXPLORATION SYSTEMS PROJECTS

Exploration Carriers Initiative

Statement of Objectives

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Baseline

Preface

This document describes the context and objectives of GSFC’s Exploration Carriers Initiative.

The Statement of Objectives is an outward-facing document intended to summarize Exploration Carriers capabilities for potential secondary payload customers. It is also intended to help establish the groundwork for building internal relationships between the Exploration Carriers Initiative and the Constellation Program as well as projects contained therein, such as the Orion Project.

The Exploration Carriers Initiative Concept of Operations (ESP-CARRIERS-OCD-001) is a companion to this document and details the operational concepts employed for Exploration Carriers missions.

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Statement of Objectives

1. Introduction

NASA has begun development of its most ambitious program for human space exploration to date. The Constellation Program (CxP) architecture not only preserves the United States' access to low earth orbit, but also provides a platform for a return to the Moon, and a foundation for human exploration of Mars and beyond. As such, the Constellation Architecture represents the "next generation" of human spaceflight systems.

The nation's last two manned spaceflight systems, the Apollo and Space Transportation System (aka., Space Shuttle) Programs, provided unprecedented access to space for the United States and its partners. In order to maximize the benefits to all, these programs established a long history of delivering small secondary payloads to orbit in an effort to further specific scientific and engineering objectives. Through these small payload programs, NASA repeatedly validated the feasibility of providing flexible, affordable access to space for scientific experiments and technology pathfinders, maximizing the nation's investment in the Apollo and Space Shuttle programs.

NASA's Exploration Systems Mission Directorate (ESMD) recognizes the extensibility of these proven and successful concepts to NASA's newest architecture for human space exploration, the Constellation Architecture. In response, ESMD has assigned leadership for small attached payloads (aka., unpressurized cargo) to Goddard Space Flight Center (GSFC). GSFC's leadership role will also extend to other ESMD programs such as the Commercial Orbital Transportation Service (COTS), managed by NASA's Commercial Crew and Cargo Program Office (C3PO).

To fully leverage the lessons of Apollo and the Space Shuttle, the adaptation of any space architecture to carry secondary payloads must also extend to the new set of vehicles and missions within the ESMD space program. In this way, NASA ensures continued availability of a delivery mechanism for small attached payloads, thereby providing new user communities with routine, rapid, low-cost access to space. Establishing programmatic parameters for this capability in the early phases of the design and development of these new system architectures is the key to ensuring that appropriate requirements are levied against the vehicle and spacecraft designs and operations. This work will also establish the framework and constraints for future payload designs that are well understood and serve the scientific and technology community utilizing this unique capability. GSFC's Exploration Systems Projects is the organization that manages and will operate the Exploration Carriers mission for NASA.

The first step in creating this programmatic framework was to establish a set of needs, goals, and objectives to focus the effort and provide the context within which requirements, system concepts and designs can be created. For the Exploration Carriers Initiative, the following applies:

1.1 Need

Routine, low-cost, low-risk opportunities for Constellation secondary payload capabilities to serve Principal Investigators (PIs) from academia, industry and government agencies to include payloads for science, technology development and future mission support.

1.2 Goal

Incorporate secondary payload capabilities throughout the architecture offered by the Constellation Program as the next major human spaceflight system.

1.3 Objectives

- Fly Exploration Carriers payloads in the Service Module of the Orion starting with Orion 1, the first Orion mission.
- Establish a Missions Operation Center and Science Operations Center at GSFC
- Develop interfaces and compatible concepts for all Constellation flight elements

2. Background

2.1 Apollo Scientific Instrument Module Bay (SIM Bay)

The Apollo SIM Bay was located on the Apollo Service Module and flew on the Apollo J missions (Apollo 15, 16 and 17). It carried up to 11 scientific and exploratory experiments designed for operation in Lunar orbit, including 2 different types of film cameras and numerous spectrometers used for characterizing the lunar surface. The camera film was retrieved during an Extra Vehicular Activity during the return trip from Lunar orbit back to earth. The Apollo SIM Bay on Apollo 15 and 16 also ejected a 78 pound sub-satellite into Lunar orbit, which carried 3 scientific experiments.

2.2 Shuttle Small Payloads Project

Two specific types of secondary payload experiment opportunities, Hitchhiker and Get Away Special, were used on the Space Shuttle, beginning with STS-4 in 1982. These projects, managed and operated by GSFC through the Shuttle Small Payloads Project (SSPP), provided quick reaction space mission capability for low cost to the scientific and technology community through a standardized, predictable and cost effective set of processes. GSFC provided end-to-end engineering and management services for SSPP customers, enabling PIs to focus on their instrumentation and science.

- The Hitchhiker project provided opportunities for experiments to fly in the Shuttle payload bay. The standard carrier system utilized by Hitchhiker was modular in order to increase flexibility for potential payloads while still maintaining standardized mechanical and electrical interfaces. These experiments could also rely on astronaut support to carry out their objectives such as requiring specific shuttle maneuvers or astronaut participation during experiment operations.
- Space Shuttle Get Away Special (GAS) payloads were similar to Hitchhiker missions, but did not require shuttle power and included only minimal astronaut intervention for successful completion. These were typically small experiments that were self contained in standardized containers and loaded into the Shuttle payload bay.

SSPP took advantage of the significant capability offered by the Space Shuttle Program to provide quick, reliable, and affordable access to space for small payloads. This program enabled hundreds of secondary payloads to fly in space, at low marginal cost.

2.3 Constellation Program (CxP)

CxP is the new human spaceflight initiative created to replace the Space Shuttle, and to position NASA for future human Lunar landings, and eventually Martian exploration. Several architectural systems of CxP offer opportunities for NASA to further its tradition of providing access to space via secondary payloads. The architecture is described below and shown in Figure 1.

- The Orion Crew Exploration Vehicle serves as the first crewed capability of the overall program. It includes a Crew Module (CM), Service Module (SM), Launch Abort System (LAS), and a Spacecraft Adapter (SA) and will be initially capable of conducting missions in low-Earth orbit, including servicing the International Space Station (ISS). Future versions of Orion are intended to add the capability to go to the Moon and Mars, once development of the Ares V launch vehicle and the Earth Departure Stage (EDS) is completed. Orion missions to ISS offer the first specific opportunity for Exploration Carriers secondary payloads.
- The Ares I launch vehicle will deliver Orion to Low Earth Orbit (LEO) via 2 stages for rendezvous with the ISS or with other CxP architecture elements depending on the particular intended mission.

- The Ares V launch vehicle is intended to deliver large unmanned cargoes to LEO such as the Earth Departure Stage (EDS) and the Altair lunar surface access module. The EDS and Altair will rendezvous with the Orion spacecraft in LEO to provide additional capability for crewed missions to the Moon and beyond.

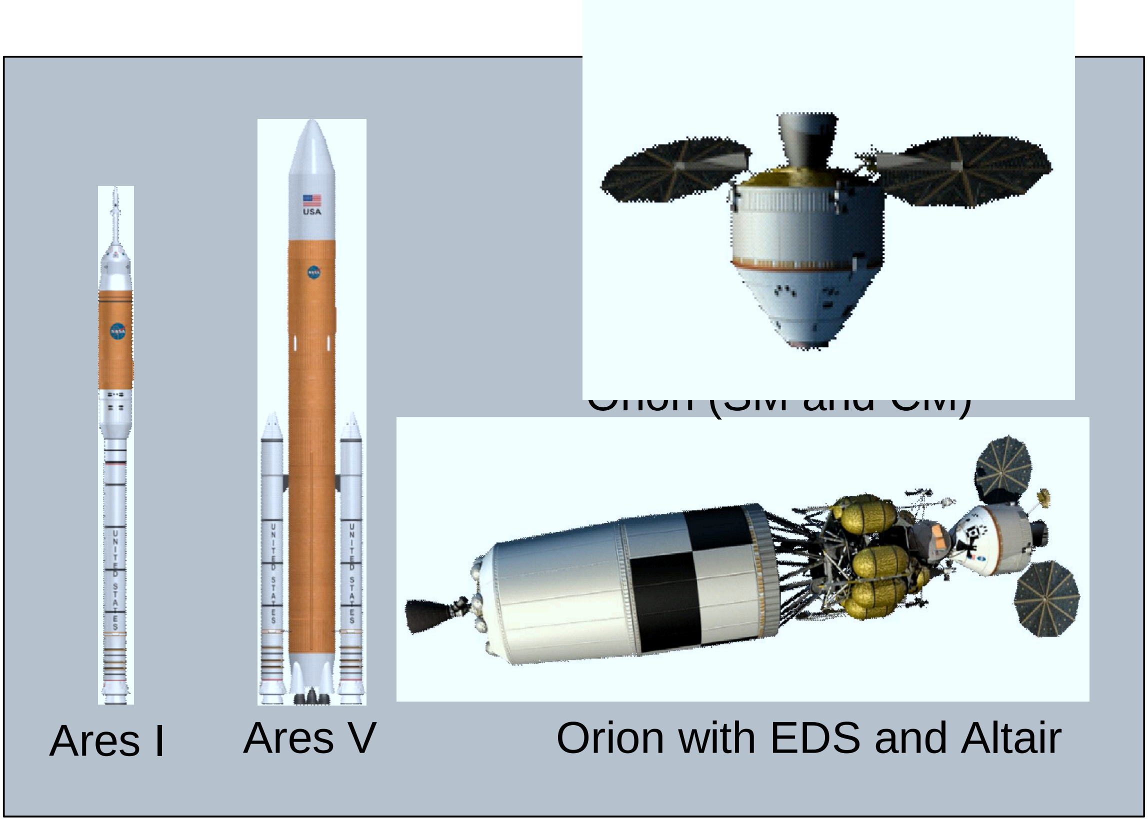

Figure 1: Constellation Architectures

While the initial focus of the Carriers Initiative is on Orion LEO/ISS missions, launched on Ares I, Exploration Carriers plans, processes, and programmatic interfaces are extensible to all other Constellation missions.

3. Purpose

The purpose of the Exploration Carriers Initiative (i.e., Exploration Carriers) is to provide a programmatic framework within ESMD from which opportunities for secondary payloads to ride-share within NASA's Constellation Architectures can be achieved. These missions will provide new and unique opportunities to complete specific mission objectives for a diverse set of customers including the science, engineering and academic communities.

During the design and development cycles of NASA's Constellation Architecture, Exploration Carriers will work with the individual system component projects, such as the Orion project, to ensure that a standardized set of interfaces are put in place to provide a stable base upon which the secondary payload customers will be able to integrate and operate their missions. This approach has been selected in order to minimize the mission-specific payload and vehicle design changes which would otherwise drive lifecycle costs higher, to maximize mission manifest flexibility, and to provide the user community with mature design parameters to use in developing payloads that have minimal risk for redesign. The various CxP Architecture components involved are shown in Figure 2 below.

Figure 2: Exploration Carriers

The Orion vehicle offers 2 opportunities for Exploration Carriers, the Cargo Bay (or Orion UPC) in the ISS configuration and the Orion SIM Bay for the lunar configuration. Future CxP opportunities may include Altair and EDS.

To further reduce the lifecycle costs associated with providing a routine, rapid access to space capability, Exploration Carriers will provide the complete set of end-to-end services necessary to manifest, integrate, test, launch and operate the customer's payload for a given mission. GSFC's in-house expertise with secondary payload development will guide customers through each phase of the mission life-cycle to ensure successful integration and mission operations. Exploration Carriers will provide recurring and standardized access to LEO and beyond for a class of payloads that help fill the gap between small sub-orbital and medium-class orbital payloads. Figure 3 below illustrates the overall payload market as it currently exists and highlights the specific segment that Exploration Carriers serves, balancing risk and cost by providing secondary payload capability within the CxP architecture.

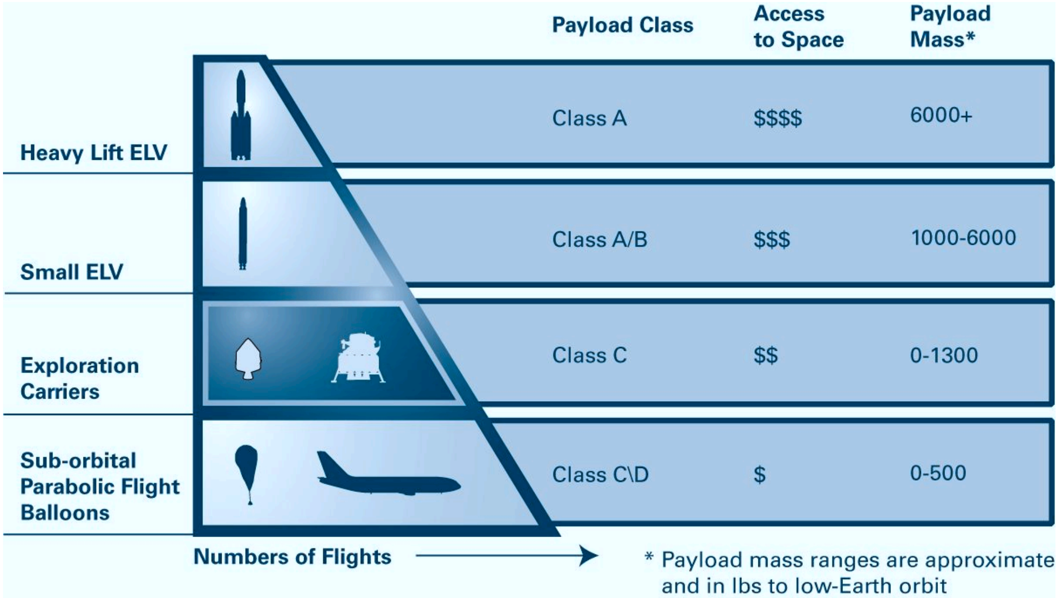

Figure 3: Payload Classes
Exploration Carriers meets the needs of users requiring low-cost access to space for small payloads

By leveraging decades of experience in the secondary payload arena on both the Apollo and Space Shuttle programs, Exploration Carriers will enable both the payload customer and the specific Constellation Architecture elements to maximize overall return on investment while reducing overall technical and programmatic risk and recurring cost.

4. Scope

Exploration Carriers will serve as the programmatic interface between the payload customer and the CxP component project, such as the Orion project, through each phase of the payload mission life-cycle, including concept, design, fabrication, test, integration, launch and mission operations. Initially, this interface is between Exploration Carriers and the Orion project. Typical activities, as well as roles and responsibilities involved in each of the life-cycle phases, are as follows:

- **Concept.** Exploration Carriers will work with the payload customer to ensure that their mission requirements align with the capabilities of an Exploration Carriers flight configuration. Exploration Carriers will work with the Orion Project team to ensure a clear understanding of the payload requirements and operations concept and provide an adequate approach to meet those requirements. Upon specific definition of any Constellation mission, Exploration Carriers will match a secondary payload with that specific mission's configuration using a predefined prioritized list of payloads, and will work with the relevant Constellation Project Office to manifest the payload appropriately.
- **Design.** Exploration Carriers will leverage its technical expertise to ensure that any specific design requirements levied by the particular Constellation Architecture elements to be utilized are fully captured and applied to the customer's payload design. Exploration Carriers will manage payload to Constellation element interfaces in order to reduce overall programmatic and technical risk to the mission
- **Fabrication.** Exploration Carriers will manage the fabrication of any scientific payload interface structures along with the standardized interface portions of the overall payload.
- **Test.** Exploration Carriers will manage the system-level payload test and verification process to ensure that all components are operating as required and that any potential issues are discovered prior to integration with the specific Constellation Architecture element.
- **Integration.** Exploration Carriers will work with CxP to ensure that the carrier payloads are properly integrated into the ground processing schedule for the appropriate flight and that the physical integration occurs per specifications. Integration and testing will occur at GSFC by Exploration Carriers prior to delivery to the Orion processing facility for installation and checkout.
- **Launch.** Exploration Carriers will represent the customer's payload in the pre-launch and launch phases of the mission.
- **Mission Operations.** Exploration Carriers will have the capability to operate the payload throughout the mission operations phase as well as to collect, process, disseminate and archive any payload data.

Additionally, Exploration Carriers will represent the payload in the integration of Safety requirements throughout the life of the Carriers project and will facilitate any technical interchange required with the appropriate organization. This includes all safety and payload integration reviews required for the specific mission involved. This will serve to ensure that all CxP safety requirements are met by the payload and that any potential issues are resolved as early as possible, and each investigator will not need to incur the cost associated with this intensive process.

5. Missions

The Exploration Carriers mission processes will be scalable and expandable throughout the evolution of the CxP, initially serving LEO/ISS missions with the Orion spacecraft, and on to Moon and Mars missions and beyond.

Initially, the Exploration Carriers will focus on secondary payloads for Orion configured for missions to the International Space Station (ISS) in Low-Earth Orbit (LEO), designated the Orion Unpressurized Cargo (Orion UPC) Project. Additionally, an Orion SIM Bay capability, analogous to the approach used by the Apollo SIM Bay, will be available on the Orion during lunar missions, as a specific volume of the SM allocated for secondary payloads. In these configurations, the carrier payload would reside within the Orion Service Module (SM) and fall under one of the three following missions types:

- **Free-flying.** Payloads that would ascend to orbit and then deploy from the Orion Service Module's cargo bay while in LEO or from the Orion SIM Bay during a lunar mission. The deployment mechanism would be considered part of the secondary payload and will be based upon the previous safety-approved mission validated mechanisms employed on Hitchhiker.
- **Extractable.** Payloads that would remain attached to the SM and are then extracted via external means, such as by the ISS Space Station Remote Manipulator System (SSRMS)..
- **Fixed-pallet.** Payloads that would remain attached for the mission duration of Orion either in the Orion UPC volume during ISS/LEO missions or in the Orion SIM Bay during lunar missions.

For the initial ISS-based mission opportunities, Exploration Carriers is developing standardized processes, procedures, and interfaces to facilitate easy integration of payloads via any of the three mission types.

Future Constellation missions involving flights to the Moon, Mars and beyond would utilize similarly standardized interfaces and processes to allow for payloads to be integrated into other pieces of the Constellation Architecture and to provide further capabilities for the payload user community. The Lunar configuration for the Orion spacecraft will provide a Scientific Instrumentation Module (SIM) Bay capability for carrier payloads. Additionally, the Lunar Surface Access Module (LSAM) Altair vehicle could be utilized to carry secondary payloads for missions such as free-flying payloads in lunar orbit, payload delivery to the lunar surface or lunar orbit loiter missions during manned missions to the Moon,

These missions are extensible and scalable from the first payload configuration on the Orion ISS missions and Exploration Carriers will provide the same types of services and operations for the payload customer as Constellation evolves. For each particular mission of interest, Exploration Carriers will serve as the customer liaison with the specific Constellation Architecture element project to help develop proper interfaces and to ensure that host system requirements, environments, manifesting concerns, and any special needs are met.

6. Performance Objectives

6.1 ISS/LEO Missions

Customers for the ISS/LEO configuration of the Orion can anticipate a carrier payload envelope on the order of 600 kg of mass and 3 cubic meters of volume. Carrier configurations for ISS missions include four modes, two of which (Mode 1 and 2) are extractable payloads to the ISS, as conceptually shown in Figure 4 below.

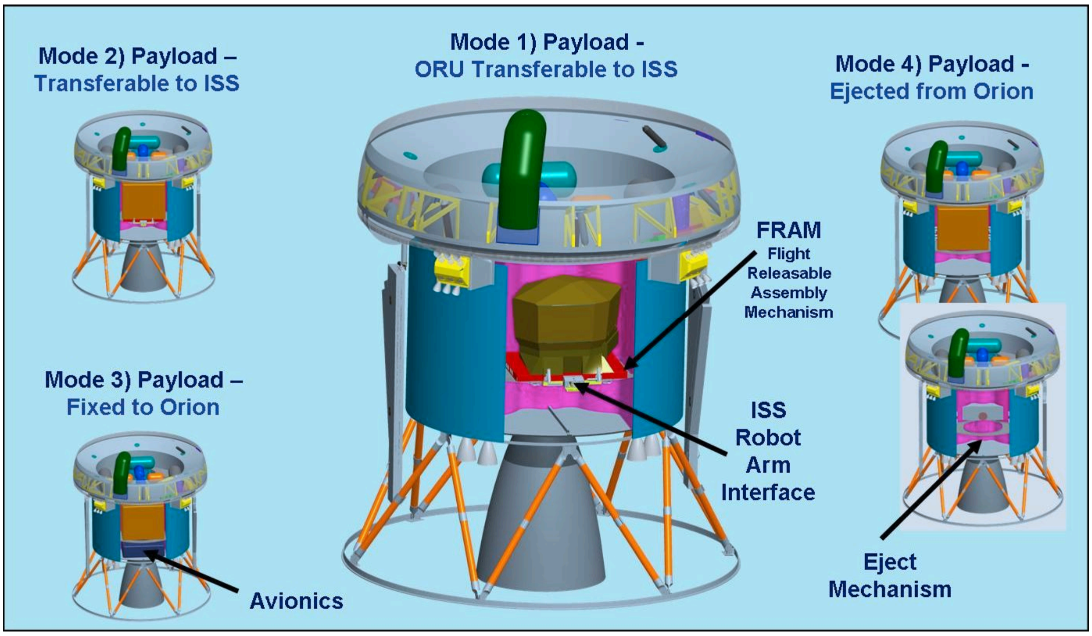

Figure 4: Carriers Conceptual Modes for ISS Missions

These figures are notional in nature and may not represent the final Orion configuration. Modes 1 and 2 are both extractable payloads delivered to the ISS

6.2 Lunar Missions

Customers for the Lunar configuration of the Orion spacecraft can anticipate a carrier payload envelope on the order of 382 kg of mass and 0.57 cubic meters of volume. This payload resides in the Orion SIM Bay located on the Service Module as shown in Figure 5.

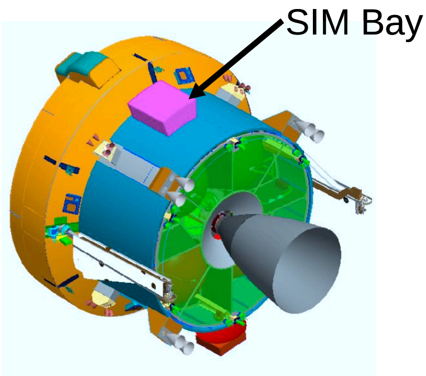

Figure 5: Orion SIM Bay

This is a notional representation of a possible SIM Bay location on the Lunar configuration of the Service Module

Exploration Carriers mission parameters utilizing the Altair or EDS will be further defined as those Constellation Architecture element designs are developed and refined.

6.3 Mars Missions

As system concepts and designs develop, the Exploration Carriers Initiative will use the same methodology and processes to manage carrier payloads for Constellation Mars missions. To date, the program is not yet mature enough to determine approximate payload mass and size envelope information for these missions.

7. Constraints

Physical size, weight, and power available to Carriers payloads are driven by the host Constellation Architecture element configuration, initially, the evolving Orion design. Therefore, the Exploration Carriers capacity is limited by individual payload envelopes to LEO, Lunar, and Mars mission constraints.

Exploration Carriers is answering a need for quick, low cost access to space. Therefore, one constraint is the ability for potential users within industry, other government entities, or academia to respond to a payload request within 12-18 months of an Opportunity Announcement to launch of a viable payload. This leads to the necessity of an industry education effort such that commercial, government, and educational entities can respond quickly to a defined "User's manual" set of expectations to enter into the Exploration Carriers mission set, and to secure funding to guarantee participation for a manifested launch opportunity.

The ultimate utility addressed here takes advantage of baseline Constellation payload capability to conduct useful science and technology investigation in place of loading the spacecraft with inert ballast that, though necessary to the mission, falls short of making full utilization of Constellation capabilities.

Deployable and extractable payloads may influence mission timelines with regards to Orion docking and LEO operations, but this impact is offset by the science and technology gains provided by the Carriers payload. Constraints therefore might be a generated set of review criteria whereby impact to the larger mission cannot be compromised by the science gained.

7.1 Design Phase Constraints

During the design phase of Orion, it is essential for the Exploration Carriers Initiative to maintain advocacy for the Exploration Carriers concept in order to maintain the baseline Orion secondary payload capability. This includes physical, power and data requirements supported by the Orion design, which enable Exploration Carriers capability. Exploration Carriers must ensure that all potential mission modes are well defined and that the appropriate requirements on the Orion design are understood, documented, adequately accommodated, and maintained as the design evolves.

7.2 Fabrication Constraints

Once the Orion design completes milestone design reviews and fabrication begins, the maximum possible payload envelope available will be definitively defined by the physical interfaces present in the available space, allowing for finalization of specific mission design constraints on the Exploration Carriers payloads.

7.3 Mission Specific Constraints

These constraints are based on the particular design configuration associated with a specific mission. The *working payload envelope* is the physical space available for the Exploration Carriers actual science/technology platform for a manifested mission after the payload overhead, such as the power system and the mechanical structure necessary, is accounted for in the design. This envelope is the actual space in which the PI can work to attain science/technology goals using their instruments and/or equipment and is a key mission specific constraint that Exploration Carriers customers will need to follow in designing their mission experiments.

8. Conclusion

Exploration Carriers is a unique national asset, evolved from a long tradition of utilizing available performance capabilities in the human spaceflight program to perform additional scientific and engineering objectives. By building upon the heritage of the Apollo SIM Bay and Space Shuttle Hitchhiker and Get Away Special projects, Exploration Carriers will keep the frontier of space open for those seeking low-cost, short timeline access to space.

While the initial emphasis for Exploration Carriers will involve payloads on the Orion spacecraft during missions to the ISS, future opportunities will include further evolution of the Constellation Program towards Lunar and Martian missions as well as other NASA projects such as the Commercial Orbital Transportation Services.

In this way, Exploration Carriers will be the ultimate source of secondary payload services within NASA and the ‘go-to’ enabler for all scientific and technology customers looking to leverage the next era of access to space for secondary payloads.

Appendix A. Abbreviations and Acronyms

Acronym	Definition
CM	Crew Module
CxP	Constellation Program
EDS	Earth Departure Stage
ESMD	Exploration Systems Mission Directorate
ESP	Exploration Systems Project
GAS	Get Away Special
GSFC	Goddard Space Flight Center
ISS	International Space Station
LAS	Launch Abort System
LEO	Low-Earth Orbit
LSAM	Lunar Surface Access Module
NASA	National Aeronautics and Space Administration
PI	Principal Investigator
SA	Spacecraft Adapter
SIM Bay	Scientific Instrument Module Bay
SM	Service Module
SSPP	Shuttle Small Payloads Project
STS	Space Transportation System
UPC	Unpressurized Cargo